

Downhole Measurement System and Method

DESCRIPTION

5 [Para 1] The following is based upon and claims priority to U.S. Provisional Application Serial No. 60/521,934, filed July 22, 2004 and U.S. Provisional Application Serial No. 60/522,023, filed August 3, 2004.

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Background of the Invention

15 [Para 2] **Field of Invention.** The present invention relates to the field of measurement. More specifically, the invention relates to a device and method for taking downhole measurements as well as related systems, methods, and devices.

Summary

20 [Para 3] One aspect of the present invention is a system and method to measure a pressure or other measurement at a source (e.g. a hydraulic power supply) and in or near a downhole tool and compare the measurements to verify that, for example, the supply is reaching the tool. Another aspect of the present is a system and method in which a gauge is positioned within a packer. Yet another 25 aspect of the invention relates to a gauge that communicates with the setting chamber of a packer as well as related methods. Other

aspects and features of the system and method are further discussed in the detailed description.

5 Brief Description of the Drawings

[Para 4] The manner in which these objectives and other desirable characteristics can be obtained is explained in the following description and attached drawings in which:

10 **[Para 5]** Figure 1 illustrates an embodiment of the present invention including a downhole tool, a supply, and alternate pressure measurements.

[Para 6] Figure 2 shows an alternative embodiment of the present invention.

15 **[Para 7]** Figure 3 illustrates an embodiment of the present invention deployed in a well.

[Para 8] Figures 4 illustrates a subsection of Figure 3.

[Para 9] Figure 5 is a schematic of the present invention and the embodiment of Figure 3.

20 **[Para 10]** Figure 6 illustrates another embodiment of the present invention in which a gauge is incorporated into a packer.

[Para 11] Figures 7 and 8 illustrate yet another embodiment of the present invention in which a gauge is provided above a packer and communicates with an interior of the packer.

1 **[Para 12]** It is to be noted, however, that the appended drawings
2 illustrate only typical embodiments of this invention and are

3 therefore not to be considered limiting of its scope, for the
4 invention may admit to other equally effective embodiments.

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7 **Detailed Description of the Invention**

8 [Para 13] In the following description, numerous details are set
9 forth to provide an understanding of the present invention.
10 However, it will be understood by those skilled in the art that the
11 present invention may be practiced without these details and that
12 numerous variations or modifications from the described
13 embodiments may be possible.

14 [Para 14] The present invention relates to various apparatuses,
15 systems and methods for measuring well functions. One aspect of
16 the present invention relates to a measurement method comprising
17 measuring a characteristic of a supply, measuring the characteristic
18 in or near a downhole tool and spaced from the supply
19 measurement, and comparing the measurements (e.g., using a
20 surface or downhole controller, computer, or circuitry). Another
21 aspect of the present invention relates to a measurement system,
22 comprising a first sensor adapted to measure a characteristic of a
23 supply, a second sensor adapted to measure the characteristic in or
24 near a downhole tool, the second sensor measuring the
25 characteristic at a point that is spaced from the supply
26 measurement. Other aspects of the present invention, which are
27 further explained below, relate to verifying downhole functions
28 using the measurements, improving feedback, providing
29 instrumentation to downhole equipment without incorporating the
30 gauges within the equipment itself and other methods, systems, and

31 apparatuses. Further aspects of the present invention relate to
32 placement of gauges in or near packers as well as related systems
33 and methods.

34 [Para 15] As an example, Figure 1 illustrates a well tool 10 attached
35 to a conduit 12. The tool has a hydraulic chamber 14, such as a
36 setting chamber, therein. The hydraulic chamber 14 may be, for
37 example, an area within the tool 10 into which hydraulic fluid is
38 supplied to actuate the tool 10. A remote source 16 supplies
39 hydraulic fluid to the well tool 10 (i.e., the hydraulic chamber 14) via
40 a hydraulic control line 18. The source 16 may be located at the
41 surface or downhole. A first sensor 20 measures a characteristic at
42 the source 16. For example, the sensor 20 may measure the
43 pressure of the hydraulic fluid at the source 16 that is supplied to
44 the control line 18. A second sensor 22 measures the characteristic
45 in the control line 18 at a position near the tool 10 and spaced from
46 the first sensor measurement. If applied to the example mentioned
47 above, the second sensor may measure the pressure in the control
48 line 18 proximal the well tool 10. Figure 1 also shows an alternative
49 design in which the alternative second sensor 24 measures the
50 characteristic in the tool 10 (e.g., in the hydraulic chamber 14). The
51 alternative second sensor 24 may be external to the tool 10 in which
52 case the sensor 24 is hydraulically and functionally plumbed to
53 measure the pressure in the tool 10. Alternatively, the sensor 10 is
54 positioned within the tool 10. The sensors 22 and 24 are described
55 as alternatives and only one may be used, although alternative
56 arrangements may use both sensors 22 and 24.

57 [Para 16] In use, the measurements from the first sensor 20 and
58 the second sensor 22 and/or alternative second sensor 24 are
59 compared. The comparison may reveal whether the supplied fluid is

60 actually reaching the tool. For example, if the control line 18 is
61 blocked the measurements between the first sensor 20 and the
62 second sensor 22 (or alternative second sensor 24) will be different.
63 If these values are substantially the same, the operator can
64 determine that the source is actually reaching the tool.

65 [Para 17] Figure 2 illustrates another aspect of the present
66 invention in which the two sensors 20 and 22 of Figure 1 are
67 replaced with a differential sensor 26 (e.g., a differential pressure
68 gauge). The measurement of the differential sensor 26 can likewise
69 indicate potential problems in and provide confirmation of whether
70 the supply is reaching the tool 10. The differential sensor 26 is
71 shown measuring the characteristic in the control line 18 near the
72 tool 10. However, as in the embodiment of Figure 1, the sensor
73 could alternatively measure the characteristic within the tool 10.

74 [Para 18] Figure 3 illustrates one potential application of the
75 present invention and a system and method of the present invention
76 applied in a multizone well 30. A lower completion 32 for
77 producing a lower zone of the well 30 has a sand screen 34, packer
78 36, and other conventional completion equipment. An isolation
79 system 40 above the lower completion 32 comprises a packer 42
80 and an isolation valve 44. The isolation valve 44 selectively isolates
81 the lower completion 32 when closed. An upper completion 50 (see
82 also Figures 4 and 5) for producing an upper zone of the well 30
83 comprises, from top to bottom, a hydraulically set packer 52 (e.g., a
84 production packer or gravel pack packer), a gauge mandrel 54, an
85 annular control valve 56, an in-line control valve 58 and a lower seal
86 assembly 60. The lower seal assembly 60 stabs into the isolation
87 assembly 40 to hydraulically couple the upper completion 50 to the
88 isolation assembly 40. Thereby, the in-line control valve 58 is in

89 fluid communication with the lower completion 32 and may be used
90 to control production from the lower completion 32. The annular
91 control valve 56 of the upper completion 50 may be used to control
92 production from the upper formation. The gauge mandrel 54
93 houses numerous pressure gauges 62.

94 [Para 19] After the upper completion 50 is placed in the well 30 the
95 annular valve 56 and the in-line valve 58 are both closed and
96 pressure is applied inside the production tubing 64 to test the
97 tubing 64. The packer 52 is then set.

98 [Para 20] In order to set the packer 52 of the upper completion 50,
99 the annular valve 56 is closed and the in-line valve 58 is opened.
100 The isolation valve 44 is closed and the pressure in the tubing 64 is
101 increased to a pressure sufficient to set the packer 52. A packer
102 setting line 66 extends from the packer 52 and communicates with
103 the tubing 64 at a position below the in-line valve 58. In this
104 example, the pressure in the tubing 64 acts as the source of
105 pressurized hydraulic fluid used to set the packer. This porting of
106 the packer 52 is necessary to prevent setting of the packer 52
107 during the previously mentioned pressure test of the tubing 64.

108 [Para 21] One of the pressure gauges 62a communicates with the
109 interior of the tubing 64, the source of the pressurized setting fluid,
110 via a gauge 'snorkel' line 68. The snorkel line 68 communicates
111 with the tubing 64 at a position below the in-line valve 58 and,
112 thereby, measures the pressure of the source of pressurized
113 hydraulic fluid used to set the packer. This pressure gauge 62a
114 provides important continuing data about the produced fluid and
115 well operation.

116 [Para 22] It is often desirable to have a second redundant pressure
117 gauge 62b or sensor that measures the same well characteristic to,

118 for example, verify the measurement of the first gauge, provide the
119 ability to average the measurements, and allow for continued
120 measurement in the event of the failure of one of the gauges.
121 Typically, the primary gauge 62a and the back-up gauge 62b are
122 ported via independent snorkel lines 68 to the substantially same
123 portions of the well. However, in the present invention, the
124 'redundant' pressure gauge 62b is plumbed to and fluidically
125 communicates with the packer setting line 66 via connecting line
126 70. Therefore, the redundant pressure gauge 62b measures the
127 pressure in the packer setting line 66 near the packer 52 at a
128 location that is spaced from the location of the measurement of the
129 first pressure gauge 62a. Both pressure gauges 62a and 62b
130 remain in fluid communication with the production tubing 64 at a
131 point below the in-line valve 58 and provide the important
132 continuing data about the produced fluid and well operation at this
133 portion of the well. However, by fluidically connecting the back-up
134 gauge 62b, the operator can determine whether a blockage has
135 occurred in packer setting line 66 between the inlet 72 and the
136 connection point 74 to the connecting line 70. Positioning the
137 connection point 74 near the packer 52 helps to verify that the
138 pressurized fluid is actually reaching the packer 52. In addition,
139 using the connection line 70 attached to the packer setting line 66
140 can reduce the amount of hydraulic line used in the completion.
141 Additionally, due to system used in the present invention, the
142 pressure gauge 62b provides a dual function of measuring the
143 pressure in the well and helping to verify that the packer 52 is set.
144 The added feature is provided at a minimal incremental cost. In
145 some cases, for example when operating in a high debris
146 environment, the packer setting line 66 may become plugged. If the
147 operator quantifiably knows that pressure either has or has not

148 reached the packer setting chamber, successful mitigation measures
149 may be more easily deployed.

150 [Para 23] Note that as mentioned above in connection with Figure
151 1, the connection point 74 may be moved to within the packer
152 setting chambers to validate the actual pressure delivered to the
153 packer 52. Additionally, as discussed above in connection with
154 Figure 2, the two pressure gauges may be replaced with a
155 differential pressure gauge to provide the verification.

156 [Para 24] Figure 6 illustrates an embodiment of the present
157 invention in which a gauge 80 is positioned within a packer 82
158 potentially eliminating the need for a separate gauge mandrel. Note
159 that the previous description and Figures 3–5 show a separate
160 gauge mandrel 54, located below the packer 52, which houses the
161 gauges 62. The present embodiment may reduce the overall
162 completion cost for some completions by eliminating the gauge
163 mandrel 54. The gauge 80 is mounted within the setting chamber
164 84 of the packer 82 in the embodiment shown in the figure,
165 although the gauge 80, may also be mounted within other portions
166 of the packer 82.

167 [Para 25] In Figure 6, the packer 82 has a mandrel 86 on which are
168 slips 88, elements 90, and setting pistons 92. Pressurized fluid
169 applied to the setting chamber 84 hydraulically actuates the pistons
170 92 setting the packer 82. In alternate designs, the pressurized fluid
171 may be applied to the packer 82 by either a hydraulic control line
172 94, which extends below the packer 82 as discussed previously or
173 which extend to the surface (not shown), or via ports in the packer
174 82 that communicate with the tubing (the discussion of Figure 7 will
175 describe such a packer).

176 [Para 26] Typically, the space available in a packer 82 outside the
177 mandrel 86 (e.g., in the setting chamber 84) is insufficient to house
178 a gauge 80 such as a pressure gauge. However, with the advent of
179 MEMS ("Micro-Electro-Mechanical Systems") and nanotechnology it
180 is possible and will increasingly become possible to make very small
181 gauges. These gauges 82 may be placed within existing packers or
182 the packers may be only slightly modified to accommodate the
183 small gauges. In addition, other customized gauges may be
184 employed.

185 [Para 27] The embodiment illustrated in Figure 6 shows a packer
186 82 that has two gauges 80 in the setting chamber 84. Control line
187 96 provides power and telemetry for the gauges 80. One of the
188 gauges 80a communicates with the central passageway 98 of the
189 mandrel 86 via port 100 and, thereby, measures the tubing
190 pressure. The second gauge 80b communicates with an exterior of
191 the packer 82 and, thereby, measures the annulus pressure.
192 Additional gauges 80 may be supplied and the gauges may be
193 positioned and designed to measure the pressure at different places
194 within the well. For example, control lines may run from the packer
195 to various points in the well to supply the needed communication.
196 Also, gauges and sensors other than pressure gauges may be used
197 to measure other well parameters, such as temperature, flow, and
198 the like. The gauge 80 could additionally be designed to measure
199 the pressure within the setting chamber 84. As discussed
200 previously, measuring the pressure in the setting chamber 84
201 provides a confirmation that the pressure in the setting chamber 84
202 reached the required setting pressure for setting the packer 82. In
203 addition, the pressure gauge 80 positioned in the setting chamber
204 84 and adapted to measure the pressure in the setting chamber 84

205 may also measure and provide continuing data about the pressure
206 via the pressure setting ports or control lines (e.g., snorkel lines).
207 Thus, a pressure gauge 80 so mounted provides the dual purpose of
208 confirming packer setting and providing continuing pressure data.

209 [Para 28] By placing the gauges 80 in the packer 82, the gauges 80
210 are very well protected while eliminating the need for a separate
211 mandrel. Eliminating the mandrel 54 also may eliminate the need
212 for timed threads or other special alignment between the packer 80
213 and a mandrel 54. In addition, the total length of the completion
214 may be reduced, the cost of equipment and the cost of completion
215 assembly may be reduced, and the electrical connections and
216 gauges 80 can be tested at the "shop" rather than at the well site, or
217 downhole. The present invention provides other advantages as well.

218 [Para 29] Figures 7 and 8 illustrate yet another embodiment of the
219 present invention in which a gauge 80 is provided above a packer
220 82 and communicates with an interior of the packer 80. The
221 embodiment of Figures 7 and 8 show a pressure gauge 80 that
222 communicates with the interior setting chamber 84 of the packer 82
223 via a passageway 102, which in turn communicates with the interior
224 central passageway 98 of the packer 82 via radial setting ports 104.
225 In this way, the pressure gauge 82 can measure the pressure in the
226 setting chamber 84 to confirm the setting pressure as well as the
227 pressure in the central passageway 98 to measure the tubing
228 pressure and provide continuing pressure information about the
229 production and the well.

230 [Para 30] The present invention may be used with any type of
231 packer. Figure 7 shows the present invention implemented in one
232 type of hydraulic packer 82. For a detailed description of a similar
233 packer, please refer to U.S. Patent Application Publication No. US

234 2004/0026092 A1. In general, the packer 82 shown has a mandrel
235 86 on which are slips 88, elements 90, and setting pistons 92.
236 Setting ports 104 extend radially through the mandrel 86 providing
237 fluid communication between an interior central passageway 98 of
238 the mandrel 86 to a packer setting chamber 84 in the packer 82.
239 The setting ports 104 communicate the tubing pressure through the
240 mandrel 86 into the setting chamber 84 of the packer 82.

241 [Para 31] The packer 82 shown is hydraulically actuated by fluid
242 pressure that is applied through a central passageway 98 of the
243 mandrel 86. The pressure of the fluid in the central passageway 98
244 is increased to actuate the pistons 92 to set the packer 82.

245 [Para 32] The figures show the gauge 80 connected to the top of
246 the packer 82. This type of connection eliminates the need for an
247 additional gauge mandrel 54. In alternative designs, the gauge 80
248 may be placed further above the packer 82 with a conduit (e.g.,
249 snorkel line) connecting the gauge 80 to the packer 82.

250 [Para 33] As mentioned above, because the gauge 80 measures the
251 pressure of the setting chamber 84, it is possible to follow the
252 setting sequences of the packer 82. The sensor also provides the
253 dual function of also measuring the tubing pressure in the packer
254 82 shown. Note that if the packer 82 is set by annulus pressure or
255 control line pressure, a gauge communicating with the setting
256 chamber 84 measures the pressure from that pressure source 16.
257 In addition, the invention of Figures 7 and 8, as well as that of
258 Figure 6, may be implemented in other types of packers, such as
259 mechanically set packers. The packer 82 may be ported in a variety
260 of ways and additional passageways or ports may be provided to
261 allow measurement at other points in the well (e.g., ports to the

262 annulus, snorkel lines to other locations or equipment in the well,
263 passageways in a mechanically-set packer, etc).

264 [Para 34] Furthermore, the inventions of Figures 6–8 may be used
265 in the confirmation system previously discussed. Specifically, in
266 both of the inventions of Figures 6 and 7–8, a pressure gauge 80
267 may be used to measure the pressure in the setting chamber 84.
268 The pressure data from the gauge 80 may be compared to a
269 measurement at the supply to confirm that the source 16 is
270 reaching the setting chamber. In addition, additional gauges 80 in
271 the packer 82 (e.g., in the embodiment of Figure 6) may be ported
272 to communicate with the source 16 to provide the desired
273 measurements while potentially eliminating the need for a gauge
274 mandrel 54. These dual gauges 80 may also provide the desired
275 redundancy discussed above depending upon the porting of the
276 gauges.

277 [Para 35] Note that in the above embodiments, the gauge is ported
278 or positioned to measure the actual or direct characteristic as
279 opposed to an indirect characteristic. For example, the gauge 80 in
280 Figure 7 is directly ported to the setting chamber 84 of the packer
281 82 and thus provides a direct measurement. This is opposed to an
282 indirect measurement in which a tubing pressure measurement
283 remotely located or not interior to the packer 82 is made to show
284 setting chamber pressure.

285 [Para 36] The above discussion has focused primarily on the use of
286 pressure gauges in packers, although some other measurements are
287 mentioned. It should be noted, however, that the present invention
288 may be incorporate other types of gauges and sensors (e.g., in the
289 packer of as shown in Figure 6 or to compare measurements from
290 two sensors, etc.). For example, the present invention may use

291 temperature sensors, flow rate measurement devices, oil/water/gas
292 ratio measurement devices, scale detectors, equipment sensors
293 (e.g., vibration sensors), sand detection sensors, water detection
294 sensors, viscosity sensors, density sensors, bubble point sensors,
295 pH meters, multiphase flow meters, acoustic detectors, solid
296 detectors, composition sensors, resistivity array devices and
297 sensors, acoustic devices and sensors, other telemetry devices, near
298 infrared sensors, gamma ray detectors, H₂S detectors, CO₂
299 detectors, downhole memory units, downhole controllers, locators,
300 strain gauges, pressure transducers, and the like.

301 [Para 37] Although only a few exemplary embodiments of this
302 invention have been described in detail above, those skilled in the
303 art will readily appreciate that many modifications are possible in
304 the exemplary embodiments without materially departing from the
305 novel teachings and advantages of this invention. For example,
306 much of the description contained here deals with pressure
307 measurement and pressure sensors, in other applications of the
308 present invention the sensors may be designed to measure
309 temperature, flow, sand detection, water detection, or other
310 properties or characteristics. Accordingly, all such modifications are
311 intended to be included within the scope of this invention as defined
312 in the following claims. In the claims, means-plus-function clauses
313 are intended to cover the structures described herein as performing
314 the recited function and not only structural equivalents, but also
315 equivalent structures. Thus, although a nail and a screw may not be
316 structural equivalents in that a nail employs a cylindrical surface to
317 secure wooden parts together, whereas a screw employs a helical
318 surface, in the environment of fastening wooden parts, a nail and a
319 screw may be equivalent structures. It is the express intention of

320 the applicant not to invoke 35 U.S.C. § 112, paragraph 6 for any
321 limitations of any of the claims herein, except for those in which the
322 claim expressly uses the words ‘means for’ together with an
323 associated function.